Jurnal Gantang VII (2) (2022): 185-197

JURNAL GANTANG

e-ISSN: 2548-5547
p-ISSN: 2503-0671

http://ojs.umrah.ac.id/index.php/gantang/index

Electronic Student Worksheets Based on Rigorous Mathematical Thinking for Sequence and Series Materials in Senior High School

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Submission: December 23th 2022; Accepted: December 25th 2022; Published: December 28th 2022
DOI: https://doi.org/10.31629/jg.v7i2.5331

Abstract

The rapid development of technology must be utilized as well as possible, especially in the world of education, because education is the basis for forming individuals who are strong and able to compete in facing the challenges of the times. The habit of students using existing formulas without knowing the concept of the material causes them to have difficulty solving the same problem but in a different form of problem. Therefore, the development of electronic student worksheets based on Rigorous Mathematical Thinking (RMT) on the material of rows and series becomes an electronic teaching material that contains the stages of the learning process to build an in-depth understanding of the concepts of students as well as being one of the changes from existing technological developments. This study aimed to assess the validity and practicality of electronic student worksheets based on RMT developed. The research method used is Research and Development (R&D) with the 4D development model. The validity and practicality assessment instrument is a student questionnaire sheet with a Likert scale. The data obtained were analyzed using the percentage of the assessment score. The validation results show that electronic student worksheets are categorized as valid, with an average percentage of material validation of 88.13%, an average percentage of media validation of 94.62%, and an average percentage of language validation 93.64%. The practicality test obtained an average percentage of 78.39% in the practical category.

Keywords: validity and practicality; electronic student worksheets; rigorous mathematical thinking

I. Introduction

In the industrial revolution 4.0, the internet revolution or IOT (Internet of Things) plays an essential role in helping almost all work done by humans, emphasizing digitization and automation in all aspects of life (Akhiruddin, Sujarwo, Atmowardoyo, & Nurhikmah, 2019). The competencies that must be possessed in the digitalization era are creative thinking skills, critical thinking, problem-solving, communication, and collaboration, commonly referred to as 4C (Kuncahyono, Suwandayani, & Muzakki, 2020). These competencies are needed to prepare adequate and competitive Human Resources (HR) to meet the demands of the 4.0 revolution era.

Education has an essential role in preparing these human resources, which in the era of industrial revolution 4.0 is called education 4.0 (Mursid & Yulia, 2019). In its role in preparing these human resources, learning 4.0, according to Laksana (2019), must emphasize a pattern of

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learning strategies that present higher-order thinking learning, such as critical thinking, problem-solving, and project learning. Another high-level thinking skill, according to Ariyana, Pujiastuti, Bestary, & Zamroni (2018), that can help prepare this HR is communication skills.

One way to support this learning strategy is to train students' Rigorous Mathematical Thinking (RMT) skills. Improving the ability to think mathematically rigorously will help students think precisely and deeply so that their ability to solve problems can increase. This follows research conducted by Aulia & Fitriyani (2019) that there is an increase in students' problem-solving ability after applying an RMT-based approach to learning. The results of Nuramalina, Hendrayana, & Khaerunnisa (2020) also inform that learning with the RMT approach can improve students' mathematical problem-solving skills.

The components of RMT in learners consist of: (1) The disposition of rigorous thinkers, which means tireless in facing challenges and having the motivation and self-discipline to persevere through goal-oriented struggles. It also requires intensive and dynamically active mental engagement; (2) The quality of a rigorous thinker who starts and is trained through mental processes that generate and perpetuate the need for certainty in thinking. The qualities of a rigorous thinker are dynamic and include sharpness in focus and perception; clarity and completeness in definition, conceptualization, and depiction of critical attributes; precision and accuracy; and depth of understanding and comprehension (Kinard & Kozulin, 2008). Thus RMT can create and maintain a higher quality of thinking, as Sumanti's (2017) research stated that the RMT approach could improve students' critical thinking skills. Janna & Salwah (2020) also significantly increased students' mathematical communication skills after applying the RMT approach.

RMT skills are based on two main theories: Vygotsky's psychological equipment theory and Feurstein's Mediated Learning Experience (MLE) theory. The psychological equipment in question comprises signs, symbols, images, and graphs used in problem-solving activities. Mediated Learning Experience (MLE) is a mediation process carried out by teachers to students during learning (Pebrianingrum, Krisdiana, & Suprapto, 2018).

There are three levels of cognitive functions required in RMT, the first level of cognitive functions is qualitative thinking, the second level of cognitive functions is quantitative thinking, and the third level of cognitive functions is abstract relational thinking (Kinard & Kozulin, 2008). The three levels of cognitive functions together define the mental process from general cognitive skills to higher-level specialized mathematical cognitive functions. In order to apply RMT to mediate learners to achieve these cognitive skills, a strong cognitive process is needed along with building mathematical concepts using three phases, namely cognitive development, content as process development, cognitive conceptual construction practice with a six-step process (Kinard & Kozulin, 2008). RMT activities according to Tyanto & Manoy (2018) consist of mediating students to define the problem, describe what to do about the given problem, analyze existing psychological tools to solve the problem, to determine the relationship between the use of psychological tools and the problem solving, to utilize and apply psychological tools to solve the problem, and to reflect on the different strategies used. The results of applying RMT activities at one of the levels can be seen in research by Pratiwi, Hauda, Kurniadi, Araiku, & Astuti (2022), which states that using the RMT approach with qualitative thinking levels can make students solve problems in detail.

Designing teaching material is one stage of planning learning activities to support and develop students to think mathematically and rigorously. As Aisyah, Noviyanti, & Triyanto (2020) stated, teaching materials determine learning success. Furthermore, using student worksheets can develop teaching material according to the educator's design and mediate

students in developing RMT skills to solve mathematical problems. Student worksheets support the implementation of the learning process. According to Darmodjo, Hendro, Kaligis, & R.E (1992), student worksheets are a learning tool that educators can use to increase the involvement or activity of students during the teaching and learning process. Besides, student worksheets can make students find concepts and train their creative thinking by playing an active role when the learning process takes place because, in the student worksheets, the answers filled in by students are in the form of open answers (Fitri, 2021). The involvement of students in finding concepts and thinking creatively is in line with the activities of the RMT stages, so students need to have the ability to think rigorously to complete the activities in the student worksheets.

In addition, Tanjung, Marneli, Delfita, & Fajar (2021) found that student worksheets provide opportunities for students to learn independently, understand written assignments, and build effective communication between teachers and students. Students' confidence and sense of success will increase when completing each activity in the student worksheets. This will be a motivation for students to continue to develop and improve their abilities. The ability to build concepts independently and follow the stages given is following the implementation of RMT skills, which focuses on mediating students in building strong cognitive processes and mathematical concepts using three phases (Wati, 2019).

The development of teaching materials using the RMT approach carried out by Khaba'ib (2021), and Anggraeni (2021) shows that the teaching materials developed using the RMT approach have valid and practical values. Rustianingsih & Manoy (2013) also researched the development of teaching materials in the form of printed Student Worksheets which are valid and practical. These previous studies related to the development of RMT teaching materials have produced printed teaching materials in student worksheets. However, following the development of Education 4.0 which is characterized by the use of digital technology in the learning process (Mursid & Yulia, 2019), it is a need to develop electronic teaching materials.

The change to electronic student worksheets does not change the content component of printed student worksheets. The thing that changed from this development was the form of presentation or media of the student worksheets. If previously the student worksheets were in the form of paper sheets, then with this change the form of student worksheets becomes electronic, where we can access student worksheets via smartphones, computers, laptops, and others as long as they are connected to the internet. The use of electronic student worksheets in learning has an impact on students' learning activities to be more enjoyable, learning becomes interactive, provides opportunities for students to practice, and motivates students to learn (Puspita & Dewi, 2021). This is in line with the opinion of Prasetyawan & Gunawan (2020) that active and fun learning is one way for students to learn mathematics optimally. In addition, electronic student worksheets have other advantages to facilitating and narrowing space and time so that learning becomes more effective anywhere and anytime (Syafitri & Tressyalina, 2020).

Keeping pace with existing technological developments, this present study aims to develop electronic teaching materials in electronic student worksheets based on RMT on the material of rows and series. This is also through consideration of preliminary data obtained in the field that the use of electronic student worksheets has yet to be maximized. The use of companion books is still the choice of educators in the learning process. This reveals that the existing technological developments have yet to optimize the learning process. In addition, it is known that students still use formulas to directly find answers without understanding the concept of the material, this results in students having difficulty in understanding application problems, especially in the material of rows and series. The same problem

was also found by Puspita & Dewi (2021) that students also have difficulty understanding math problems. Suppose the form of the problem given differs from the example problem the educator explains. The need for more understanding of students' concepts can be helped by practicing RMT skills. Therefore, RMT-based electronic student worksheets are needed.

Based on the background stated above, research titled "Test the validity and practicality of electronic student worksheets based on RMT on the material of rows and series in class XI SMA" should be conducted.

This article shows the validity and practicality of the electronic student worksheets based on RMT on the material of rows and series of grade XI SMA.

II. Research Method

This study aims to test the validity and practicality of electronic student worksheets based on Rigorous Mathematical Thinking (RMT) on the material of rows and series. The type of research conducted is R&D (Research and Development) research which aims to produce a product and test its feasibility (Sugiono, 2016). The development model used is 4D which consists of 4 stages, namely the defining (Define), designing (Design), developing (Development), and disseminating (Disseminate) stages. Expert test subjects were 3 lecturers from the Faculty of Teacher Training and Education, Raja Ali Haji Maritime University, and 2 high school mathematics teachers. Product trial subjects were 20 students of class XI IPS 2 SMAN 4 Tanjungpinang as electronic student worksheets users to see the practicality of RMT-based electronic student worksheets on the material of rows and series.

The data collection technique used is to provide a series of written statements or explanations to validators and respondents/students to be answered according to their assessment and experience while using electronic student worksheets. The research instrument used is a set of questionnaires. Electronic student worksheets validation and practicality questionnaires are measured using a Likert scale with five rating scales. Details of the measurement scale used can be seen in table 1,

Table 1.
Guidelines for Likert scale levels

Level	Description	Score
SS	Strongly agree	5
S	Agree	4
C	Quite agree	3
TS	Disagree	2
STS	Absolutely disagree	1

The data obtained from the questionnaires are analyzed using a percentage score of the following formula adapted from Sholehah (2021)

$$p = \frac{\sum x}{\sum xi} \times 100\%$$

Description :
p = percentage
$\sum x$ = Total score obtained
$\sum xi$ = The ideal score

The score percentage criteria adapted from Arikunto & Cepi Abdul Jabar (2018) can be seen in table 2,

Table 2.
Practicality category interval

Validity Category	Interval	Practicality category
Very valid	81% – 100%	Very practical
Valid	61% – 80%	Practical
Quite valid	41% – 60%	Quite practical
Less valid	21% – 40%	Less practical
Invalid	0% – 20%	Impractical

III. Results and Discussion

Electronic student worksheets based on RMT on the material of rows and series in class XI SMA is developed based on the 4D model,

which in this study until 3 D, namely define, design, and developing stages.

1. Define.

This stage is the problem identification stage to obtain information related to the product to be developed. At this stage, researchers found that the learning process still uses a hybrid system where part of the learning process still occurs online. The teaching materials are still printed and have yet to be combined with digital or electronic teaching materials. Then based on the educator's information, it is known that students have difficulty solving problems in the form of applications on the material of rows and series. This shows that students' understanding of the concept of material could be stronger.

In this development, the formulation of concepts that refer to the basic competencies and achievement indicators listed in the 2013 curriculum is carried out to identify the skills to be learned on the material of rows and sequences. The concept of the material prepared is adjusted to the learning strategy 4.0 presented by Laksana (2019).

One of the skills that can support this strategy is Rigorous Mathematical thinking (RMT). So that the concept of this material is also adjusted to the steps of understanding RMT. There are six steps to understanding the RMT context: adjusting the model, displaying psychological tools, building basic concepts, finding formulas, adjusting psychological tools, and applying psychological tools.

2. Design

The student electronic worksheet was carefully selected to obtain media that can support the E-LKPD development process. In terms of development, question design features, ease of access, and use. Based on these considerations, the live worksheets platform was chosen.

Learning videos were inserted in this student electronic worksheet so students could watch to understand the outline of the row and sequence material being studied. In developing E-LKPD, researchers designed the content of E-LKPD following the theory of Rigorous Mathematical Thinking. Where in the E-LKPD there are three phases and six steps that will guide students in understanding the material of rows and series.

The three phases and six steps are:

1. Cognitive Development

a. Adjusting the Model in this activity, the researcher designs so that students are given examples of rows and series problems, then mediated to adjust the model or visualize based on the problems given so that the problem form of the problem given can be seen.

b. Displaying psychological tools. From the problem model seen earlier. Furthermore, the researcher designs so that students can use the psychological tools they have before such as symbols, tables, schemes, and other information, to solve the problems given so that students can find patterns of rows and series of existing problems.

2. Content as Process Development

a. Building basic concepts. The next activity is designed so students can conclude the row and sequence material concept according to the characteristics and patterns found. At this stage, the results that students will write vary according to their respective understanding.

b. Finding the formula. After understanding the concepts and patterns of rows and series material, the next activity is designed to mediate learners in analyzing and finding general formulas so that learners understand the concept of using formulas well.

c. Adjusting psychological tools. At this stage, learners are mediated to solve the given rows and series problems using the appropriate formulas and psychological tools to obtain the correct answers.

3. Cognitive conceptual construction practice.

In this last stage, students are mediated to practice using each psychological tool, including the formulas of rows and series that have been formulated. At this stage, cognitive tasks given are modified to several levels following the level of thinking RMT. In order to train the use of

cognitive functions in building mathematical, conceptual understanding.

3. Development

At this stage, the instruments and electronic student worksheets that have been designed are tested for validity by validators. The product validation assessment is used to determine the feasibility of the electronic student worksheets product developed. Three validators will test the validity of the electronic student worksheets, namely material validators (consisting of one mathematics education lecturer and one mathematics teacher), media validators (consisting of one mathematics education lecturer and one mathematics teacher), and language validators (consisting of one Indonesian language and literature education lecturer and one mathematics teacher). This follows the opinion of Fahrurrozi & Mohzana (2020) that there are three product validations, namely (1) content expert validation, (2) design expert validation, and (3) language expert validation. The results of the electronic student worksheets validation developed are as follows.

The results of the electronic student worksheets validation developed are as follows.

a. Material expert validation

Material expert validators comprised one UMRAH mathematics lecturer and one high school grade XI mathematics teacher. The material expert was given a validation sheet to assess the electronic student worksheets developed. The material expert validation sheet contains aspects of 1) content feasibility, this aspect contains statement items related to the completeness and suitability of electronic student worksheets content with the applicable curriculum and the depth of electronic student worksheets material; 2) aspects of RMT ability; this aspect contains statement items related to the suitability of the electronic student worksheets steps developed with the RMT understanding stage and; 3) aspects of presentation feasibility, this aspect contains statement items related to the systematic presentation of electronic student worksheets. These three aspects were then derived into 16 statement items. Furthermore, the validation results obtained were processed by calculating the average percentage of the data. This stage was completed with the help of Microsoft Excel 2010. The results obtained from data processing are valid with a percentage of 88.13%. The following are the results of the material expert validation calculation.

Table 3.
Material expert validation results

No	Aspect	Average (%)	Criteria
1	Content feasibility	87,14	Very valid
2	Rigorous Mathematical Thinking Ability	88,57	Very valid
3	Presentation feasibility	90	Very valid
Overall results of material validation		**88,13**	**Very valid**

The improvements given by material expert validators for the developed electronic student worksheets are 1) Enlarge the video display so that students can understand the learning video provided, and 2) Eliminate images that have no function or relationship in the material so as not to cause confusion or miscommunication for students/users.

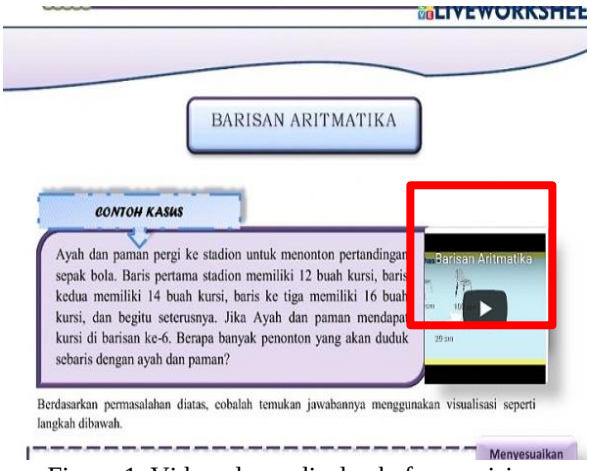

Figure 1. Video player display before revision

Video displays that are too small make it difficult for students to understand the material presented due to the illustrations that look not so clear.

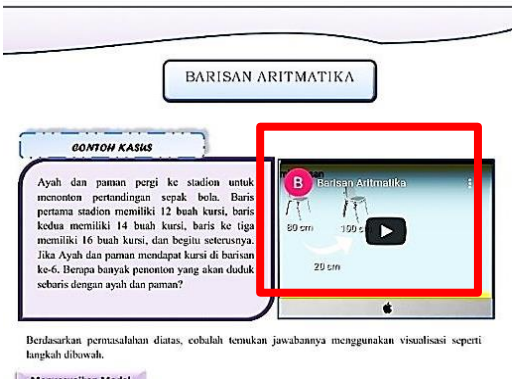

Figure 2. Video player display after revision

b. Media expert validation

Media expert validators comprised one UMRAH mathematics education lecturer and one mathematics teacher. Media experts were given a validation sheet to assess the electronic student worksheets developed. On the media expert validation sheet, there is 1) the convenience aspect; this aspect contains statement items related to the ease of accessing and using the developed electronic student worksheets; 2) the layout aspect, this aspect contains statement items related to the systematic preparation of electronic student worksheets and; 3) display aspect, this aspect contains statement items related to the colors, images, and text that appear in the electronic student worksheets. These aspects were then derived into 13 statement items. The validation results were processed by calculating the average percentage of data owned. This stage was completed with the help of Microsoft Excel 2010. The results obtained from the data processing are very valid, with a percentage of 94.62%. The following calculation results of media expert validation can be seen in table 4,

Table 4.
Media expert validation results

No	Aspect	Average (%)	Criteria
1.	Ease	92,50	Very valid
2.	Layout	100	Very valid
3.	Display	94,29	Very valid
Overall results of media validation		**94,62**	**Very valid**

In addition, media expert validators also provided suggestions for the electronic student worksheets to be revised. The input from validator I and validator II is that the image on the cover is adjusted to the content of the material, then use contextual images that follow mathematical concepts by changing the size of the image according to the correct comparison concept. In addition, the appearance and presentation of the electronic student worksheets developed are good and can be used as teaching materials.

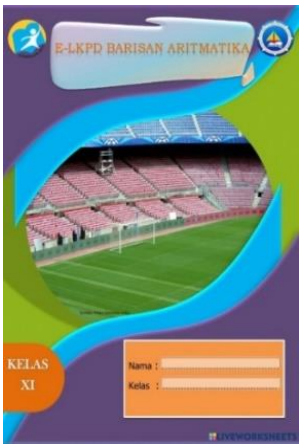

Figure 3. Cover view before revision

Before the revision, all electronic student worksheet covers looked like the picture above in figure 3. After revision, each electronic student worksheet's cover contains a picture representing the sub-material/topic discussed.

Figure 4. Cover view after revision

In addition to the cover's appearance, the validator also provided suggestions regarding the inappropriate comparison in the images displayed.

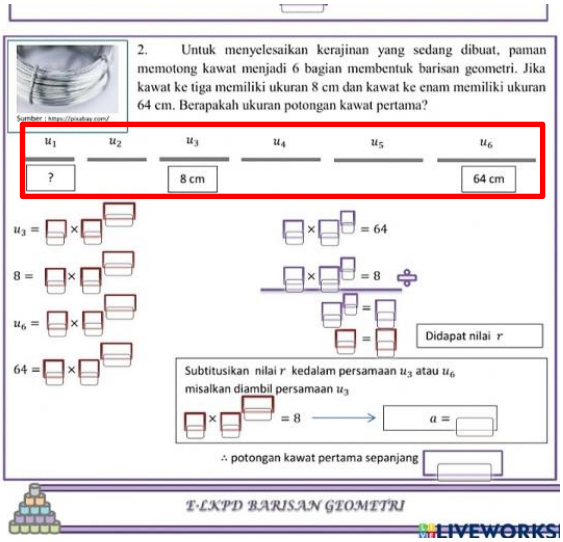

Figure 5. Comparison of images before revision

The picture showing the wire cut does not match the comparison narrative given. Once corrected, here is what the comparison should look like.

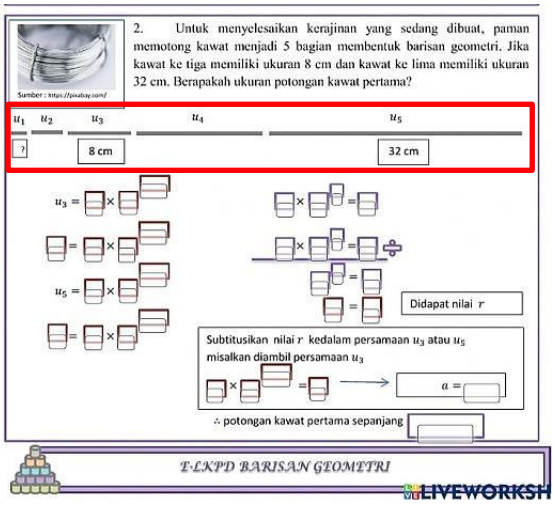

Figure 6. Image comparison after revision

c. Language expert validation

The linguist validators comprised one UMRAH Indonesian language and literature education lecturer and one math teacher. Linguists were given a validation sheet which was used to assess the developed electronic student worksheets. Linguists were given a validation sheet to assess the electronic student worksheets developed. On the linguist validation sheet, there are 1) aspects of readability, this aspect contains statement items related to the sentences that are compiled clearly and easily understood; 2) aspects of conformity with language rules, this aspect contains statement items related to the use of Indonesian language rules in the sentences compiled and; 3) aspects of language use, this aspect contains statements related to the clarity and correctness of the use of language used. This aspect is then reduced to 11 statement items. This assessment was conducted to assess the feasibility of the language used in developing electronic student worksheets. The following linguist validation results can be seen in table 5.

Table 5.
Results of language expert validation

No	Aspect	Average (%)	Criteria
1.	Readability	94,00	Very valid
2.	Conformity with Indonesian language rules	90,00	Very valid
3.	Use of language	96,67	Very valid
Overall results of language validation		**93,64**	**Very valid**

In addition, the linguist validator also gave suggestions for the electronic student worksheets to be revised. The input from validator I and validator II is improving the use of capital letters that need to be more consistent. In addition, the electronic student worksheets developed are good and can be understood well, and the layout and language are easy to understand.

Overall, the validity assessment of RMT-based electronic student worksheet products on the material of rows and series meets the valid criteria. This can be seen from the validation sheets of material experts, media experts, and linguists with valid categories. Researchers received some suggestions from the experts, which were used to revise the electronic student worksheets developed to be better. Furthermore, the electronic student worksheets developed will

be tested for practicality to educators and students.

After the product is declared valid and revisions have been made based on expert suggestions. Researchers conducted a practicality test with the subject 20 students of class XI IPS 2 and 1 math teacher.

d. Product practicality

Practicality assessment is carried out based on the responses of students and educators after using the developed electronic student worksheets (Rosliana, 2019). Educators and students are given a practicality sheet to assess the ease of use of the electronic student worksheets developed. The results of the practicality obtained are processed by calculating the average percentage of data owned. This stage was completed with the help of Microsoft Excel 2010. The results obtained from the data processing were practical, with a percentage of 78.39%. The following data obtained from the practicality test can be seen in table 6.

Table 6.
Student response questionnaire results

No	Aspect	Average (%)	Criteria
1.	The ease of using E-LKPD	77,86	Practical
2.	Content E-LKPD	76,57	Practical
3.	Display	81,90	Very practical
4	Benefit	80,48	Very practical
The overall result of student practicality		**78,39**	**Practical**

Overall, the assessment of the practicality of RMT-based electronic student worksheet products on the material of rows and series meets the practical criteria.

Given the importance of high-level thinking skills in this 4.0 revolution era, education has become one of the spearheads in preparing qualified human resources. However, seeing the results of the defining stage where the understanding of the concept of students who are not yet strong on the material of rows and series makes researchers develop RMT-based electronic teaching materials to train students' conceptual understanding. RMT was chosen because, in its stages, it mediates students build their conceptual understanding. This was also conveyed by Hendrayana (2017) in his research that the RMT approach has familiarized students with building concepts by understanding mathematical culture. Similar results are also seen from research by Aulia & Fitriyani (2019) and Nuramalina et al. (2020) that the RMT approach improves students' solving skills.

As stated, Aisyah et al. (2020) related that teaching materials determine learning success. So that at the design stage, electronic worksheets were chosen as the final product produced, given the functions and advantages they have in the learning process, as stated by Tanjung et al. (2021). Besides that, electronic worksheets were developed to provoke higher-order thinking learning characteristics, as stated by Laksana (2019). Given the difficulties faced by students in the field, in this case, the electronic worksheet was developed based on RMT, which contains three phases and six steps of the RMT stage, as stated by Kinard & Kozulin (2008).

After the RMT-based electronic worksheets were designed, they were tested for validity and practicality. Electronic student worksheets are validated using an instrument such as a questionnaire sheet by experts. Teaching material is valid if the teaching material is of good quality and focuses on the material and learning theory used. For this reason, expert validation of the electronic student worksheets developed is very necessary. According to Pebrianingrum et al. (2018), validation is carried out to obtain the validity of the product produced, so experts are needed as validators to assess the product using the validation sheet provided.

The results of the validation assessment (material, media, and language) of electronic student worksheets by experts are on average valid. Electronic student worksheets are categorized as valid, as seen from the electronic student worksheets' construction steps following

the RMT activity base so that it supports the achievement of basic competency and indicators in learning. She was following one of the principles of selecting teaching materials, namely relevance, which means that the activity steps in the electronic student worksheets are related to the essential competencies and indicators in learning (Robin, Suryono, & Wijianto, 2017). This follows Anggraeni's (2021) previous research, which also used the principles of selecting teaching materials in developing her electronic student worksheets.

Another supporting aspect is the selection of contextual images and accordance with the material to ensure the learning process is clear. Following Riwu, Laksana, & Dhiu's (2019) research in developing electronic teaching materials, images of the material used in the developed teaching materials must be contextual. In addition to displaying images, using language following Indonesian language rules in the sentences used in electronic student worksheets also supports the validity of the electronic student worksheets. Following the research of Gustiawati, Arief, & Zikri (2020) that language validation is needed to evaluate the language used in the teaching materials that have been developed.

The practicality test of the developed electronic student worksheets is measured through the educator and learner practicality instruments. Teaching material is practical if the teaching material can be used easily by educators and students (Kurnia, 2019). In line with the opinion of Fahrurrozi & Mohzana (2020) that student worksheets are practical if they get at least a positive response from students seen based on the student response scale. From here, users can know and feel the level of applicability. Users can find out the advantages or disadvantages in relevance, accuracy, readability, language, and suitability for learner-centered learning. Therefore, users can provide input or improve the developed teaching materials.

The developed electronic student worksheets are categorized as practical, with a response percentage of 78.39%. Overall, educators' and students' responses to the electronic student worksheets developed meet the practical category in terms of ease of use, content, appearance, and benefits of electronic student worksheets. This can be seen from simple live worksheet media that makes it easier for students to fill in the steps of RMT activities and know the work results directly. According to the research of Rhosyida, Muanifah, Trisniawati, & Hidayat (2021), students and parents can easily and quickly see their learning results. These electronic student worksheets also make it easier for students to find the correct answers provided by educators to evaluate themselves on the results received.

Thus, overall it is obtained that the development of RMT-based electronic student worksheets on the material of rows and series in class XI SMA meets the valid and practical criteria and can be continued at the effectiveness stage. Following the opinion of Maskar & Dewi (2020) that the R&D method generally uses validity, practicality, and effectiveness tests on the products tested. So that further research can be continued with the effectiveness test.

IV. Conclusion

Education in the era of revolution 4.0 encourages students to be able to compete intellectually and technologically. Electronic student worksheets based on RMT, an electronic teaching material developed following three phases and six process steps. In the process's three phases and six steps, students are mediated to develop mathematical thinking skills from the general cognitive thinking level to reach a higher level of cognitive thinking.

Validators and users have also tested the developed electronic student worksheets to assess their feasibility and ease of use of the electronic student worksheets. So that valid and practical values are obtained. Therefore, the electronic student worksheets based on RMT can be continued to the effectiveness test stage.

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